Comparison of Intertidal Invertebrate Assemblages at Four Sites around Rottnest Island, Western Australia After Seven Years of Marine Heatwaves

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ABSTRACT

A study aiming to compare the abundance and species composition of invertebrates among four sites (Strickland East (SE), Strickland West (SW), Strickland Far East (SF) and North Point (NP)) on intertidal rocky platforms around Rottnest Island, Western Australia was conducted in January 2018. Eight quadrats with 1m by 1m dimension were haphazardly placed at each of three zones in the sampling site including inner, middle and outer zone in relation to the shoreline in order to obtain the data of invertebrate community structure. The result of one-way ANOVA test with robust covariance matrix showed that the intertidal invertebrate abundance among four sampling sites was significantly different (P<0.05). Then, a further test using Tukey post hoc analysis found that invertebrate abundance at SE was significantly different with the assemblage of invertebrate at NP, SW and SF at the level of significant of 1%, 5% and 10%, respectively. Whereas the cluster analysis revealed that there were two clusters of invertebrate species at Rottnest Island. In the future, it is recommended to conduct an invertebrate community structure monitoring program consistently every year covering all intertidal sites around Rottnest Island in order to obtain reliable data useful for conservation and management purposes.

Keywords: comparison, abundance, species composition, invertebrates, intertidal, Rottnest Island

ABSTRAK

Sebuah kegiatan penelitian yang bertujuan untuk membandingkan kelimpahan dan komposisi jenis invertebrate di 4 lokasi (Strickland East (SE), Strickland West (SW), Strickland Far East (SF) dan North Point (NP)) habitat berbatu daerah intertidal yang terletak disekitar Pulau Rottnest, Australia Barat telah dilakukan pada bulan Januari 2018. Pengambilan data struktur komunitas invertebrate dilakukan dengan cara meletakan secara acak 8 kuadrat berukuran 1 x 1m2 pada setiap zona penelitian (terdiri dari 3 zona: luar, tengah dan dalam) yang mengacu pada garis pantai di setiap lokasi penelitian. Hasil uji ANOVA satu arah menunjukan bahwa kelimpahan invertebrate intertidal pada ke-empat lokasi penelitian berbeda secara signifikan (P<0.05). Kemudian, hasil uji lanjut menggunakan analisis Tukey post hoc memperlihatkan bahwa kelimpahan invertebrate di SE berbeda signifikan dengan kelimpahan invertebrate di NP, SW dan SF pada tingkat kepercayaan 1%, 5% dan 10% secara berturut-turut. Sedangkan hasil analisis cluster mengungkap bahwa terdapat 2 kluster spesies invertebrate di Pulau Rottnest. Hasil penelitian ini merekomendasikan perlunya dilaksanakan program monitoring struktur komunitas invertebrate secara konsisten setiap tahun yang mencakup semua habitat intertidal di sekitar Pulau Rottnest untuk mendapatkan data yang berguna bagi kegiatan konservasi dan pengelolaan sumber daya hayati perairan Pulau Rottnest.

Kata kunci: perbandingan, kelimpahan, komposisi spesies, invertebrata, intertidal, Pulau Rottnest.

1. Introduction

As one of marine intertidal community components, invertebrates play an important role in maintaining a stable and healthy marine ecosystem. This group of animals are ecologically and economically useful to the environment and societies who live along the coast line. Macrobenthic invertebrates are ecologically beneficial bioindicators offering a more comprehensive understanding of fluctuating aquatic conditions than chemical and microbiological data (Gray, 2000). Many of invertebrates act also as filter feeders where they suck in small food particles from the water column into their digestive system. This role enabling them to form the chemical and biotic composition of their ecosystem.

However, the life of intertidal invertebrates at Rottnest Island, Western Australia, currently, is threated by a rise in temperature in Indian Ocean which is adjacent to Western Australia's sea water (Hobday & Pecl, 2014). During austral summer in 2011, south-west coast of Australia including Rottnest sea waters was impacted by Leeuwin current delivered anomalously warm water (Feng et al., 2013). Meanwhile, Wernberg et al. (2012) reported that in the beginning of 2011, Western Australia marine waters experienced extreme climatic events called marine heatwaves. During that year, the sea surface temperature (SST) increased to the unprecedented level and warming anomalies of 2-4o C persisted for more than ten weeks along more than 2,000 km of coastline. Another report stated that during February and March 2011, sea water temperatures off south-western coast of Western Australia increased to unprecedented levels with peak nearshore temperature increasing to ~5oC above average in the central west coastal region in the period of seven days in late February and early March (Pearce & Feng, 2013). These events occurred caused by several factors including unusual strong La Niña conditions, strong Leeuwin Current in West Coast Australia and anomalously heat flux between atmosphere and sea surface (Pearce et al., 2011, Pearce & Feng, 2013).

Marine heatwaves had given adverse effects on invertebrate assemblages since the majority of intertidal invertebrate species are the member of low trophic levels. Therefore, they respond faster to changing in climate than species at higher trophic levels (Jenouvrier et al., 2003). In terms of global scientific study on the effect of marine heatwaves on the community structure of invertebrate assemblages, there were several scientific studies in regards to this topic such as the research on the impact of 2003 marine heatwaves on benthic community structure of a transitional ecosystem in Italy by Munari (2011) and the study on the effect of 2015 marine heatwaves on benthic invertebrates in the Marine Protected Area, Tabarca, Southeast Spain by Rubio-Potillo et al. (2016). Both studies revealed that there were shifts in invertebrate community structure affected by marine heatwaves. In Rottnest Island, however, there is no research focusing on the community structure of intertidal invertebrates after a marine heatwaves event in 2011. Therefore, this study aims to compare the abundance and species richness of intertidal invertebrates among four sites (Strickland East, Strickland West, Strickland Far East and North Point) around intertidal zone of Rottnest Island waters after seven years of marine heatwaves was occurred. It is hypothesized that there will be no significant different in community structure of invertebrate assemblages among four research sites around Rottnest island after an event of marine heatwaves along Western Australia Coast in 2011.

2. Materials and methods

2.1. Study area

The study was conducted at several sites in intertidal zones around the Rottnest Island which is situated 18km west of Fremantle, Western Australia. There were four sampling sites around Rottnest Island including North Point, Strickland East, Strickland Far east and Strickland West (Figure 1). The substrate at each study site was an intertidal rock platform dominated by turf algae. The intertidal invertebrates used the turf algae as the shelter and food source. In several spots of the platform, there were also perforated rocks functioned as shelters for many sea urchins. The intertidal rocky dominated platforms extend to approximately 100 meters long to the neritic zone.
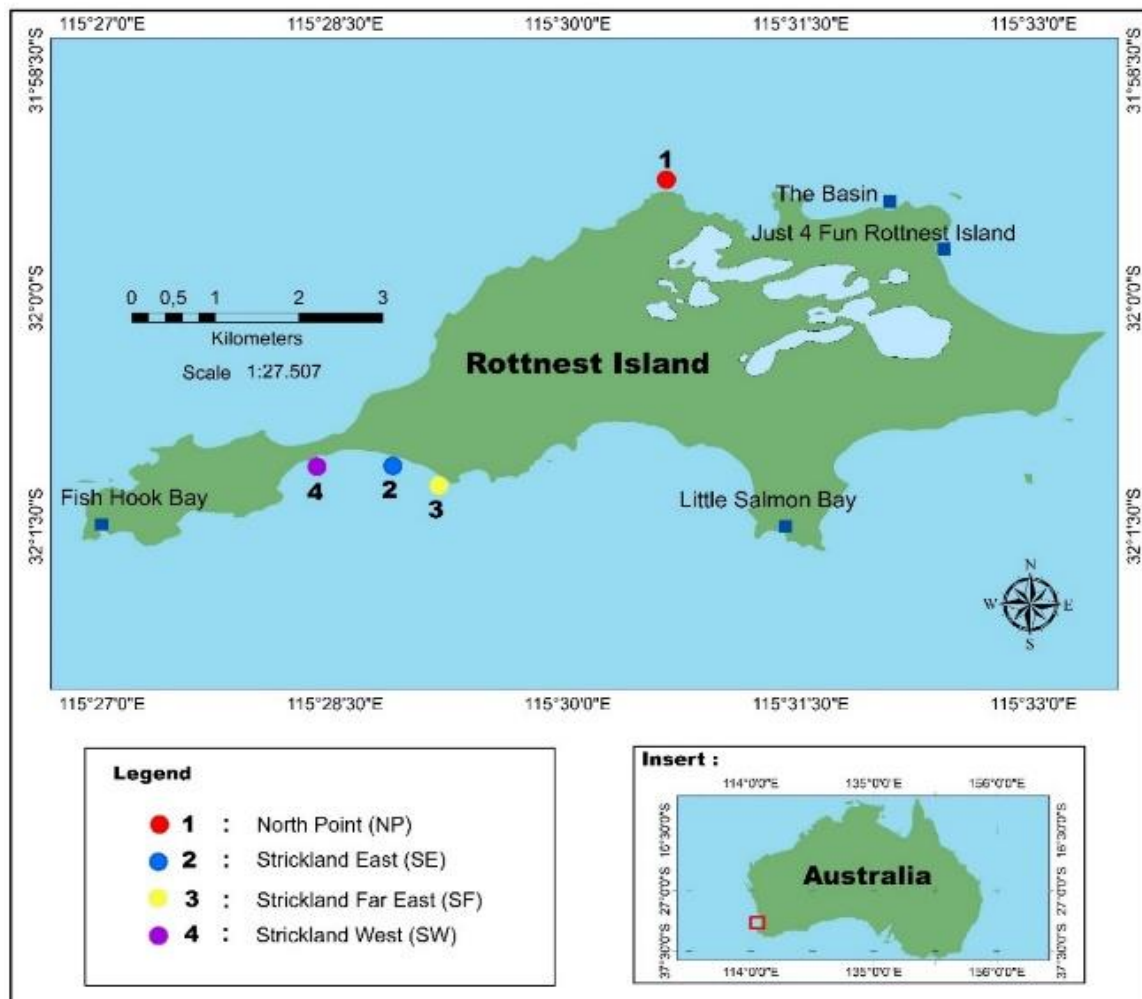
Figure 1. Map of study location with four sampling sites around Rottnest Island, Western Australia.

2.2. Sampling technique

In order to test the prediction, the research activities were haphazardly conducted at four sampling sites in summer time (January 2018). Each of four sampling sites was divided into three zones namely outer, middle and inner in relation to the shoreline (Figure 2). A Quadrat with 1m by 1m dimensions was haphazardly placed eight times at each of the three zones. Therefore, totally there were 24 plots considered as replications at each sampling site.

The sampling activity of intertidal invertebra- tes was conducted during low tide so that the identification process of invertebrate species was easier because the wave was less strong. Then, the in-situ identification was conducted based on the guideline of an identification sheet (source: Parish and Jones, 1996; Edgar, 2000) in order to avoid the erroneous identification among the investigators. The species of invertebrate was specified into groups including Echinodermata, Mollusca,

Porifera, Cnidarian and other phyla. Then, each species was counted per meter quadrat square individually except for colony species such as corals in which each colony was regarded as one count.

2.3. Data analysis

The raw data of the number of individuals of all invertebrate species at each sampling site was pooled first into Microsoft Excel worksheet in order to perform quantitative analysis over the period. Then, R software (version 3.3.2) was used to perform all statistical analysis and visualize the boxplot. To test whether there was a significant difference of invertebrate abundance at four sampling sites (SE, SF, SW and NP) after the 2011's marine heatwaves event, a one-way analysis of variance (one-way ANOVA) was performed. However, before conducting the one-way ANOVA analysis, Bartlett test was performed first to test the homogeneity of data variance. If the variance of the data was
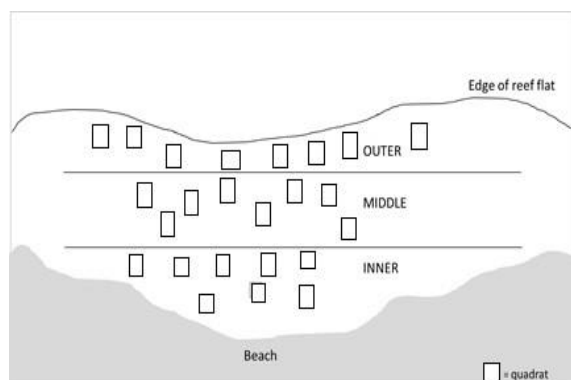
Figure 2. Layout of three zones of the sampling site (inner, middle and outer) with eight quadrats at each zone.
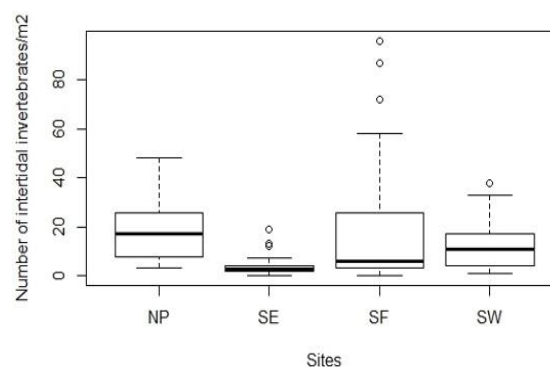

Figure 3. The boxplot of invertebrate abundance data with 24 replications at each study site. NP = North Point; SE = Strickland East; SF = Strickland Far East and SW = Strickland West.

homogen (P>0.05), then a usual One-way ANOVA would be performed, but if the data variance was not homogen (P<0.05), then a one-way ANOVA with robust covariance matrix would be executed in order to transform the data to meet the assumption of homogeneity of variance. If the result of ANOVA test showed that there was a significant difference (P<0.05), then the Tukey post hoc test would be performed to reveal the difference in invertebrate assemblages among four sampling sites (Underwood 1997). Furthermore, a cluster analysis with Bray Curtis similarity method using Primer software (Version 6) was applied to investigate sampling sites which had similarity in invertebrate species composition (Clarke & Warwick, 2001).

3. Results and discussion

The highest abundance of intertidal invertebrates was found at Strickland Far East with 497 individuals. Meanwhile, the lowest abundance and species richness of intertidal invertebrates were investigated at Strickland East with 97 individuals and 16 species, respectively. Whereas the North Point had the highest species richness with 29 species of intertidal invertebrates (see details in Table 1).

The result of Bartlett test found that the variance of the invertebrate abundance data with 24 replications at each sampling site was not constant (P<0.05). This might be occurred since there were some outliers of the data at several sampling sites including Strickland East,

Strickland Far East and Strickland West (Figure 3). Therefore, to meet the assumption of homogeneity of variance, one-way ANOVA test with robust covariance matrix was performed to investigate the difference in invertebrate assemblage among four sampling sites. As the result of ANOVA test showed that there was a significant difference in abundance of intertidal invertebrate among the four sampling sites (P<0.05), then, Tukey post hoc test was executed to further investigate the difference.

Tukey test results showed that invertebrate abundance at Strickland East was significantly different with the abundance of invertebrate at North Point, Strickland West and Strickland Far East at the level of significant of 1%, 5% and 10%, respectively. Whilst invertebrate abundance among the other sampling sites were not significantly different (P>0.05) (Table 2).

The last test using cluster analysis with Bray Curtis similarity method revealed that there were two invertebrate species composition clusters around intertidal zone of Rottnest Island. The first cluster included three sampling sites (Strickland East, Strickland West and Strickland Far East) where Strickland East and Strickland West had the highest similarity level, followed by Strickland Far East. Whereas North Point became a single cluster separated from the first cluster since it had low species composition similarity with the other three sampling sites (Figure 4).

Table 1. The abundance and species richness of marine intertidal invertebrates at four sampling sites around Rottnest Island. SE = Strickland East; SW = Strickland West; NP = North Point and SF = Strickland Far East

List of Invertebrates	Sites			
	SE	SW	NP	SF
Pink Bryozoan	0	0	2	0
White Ascidian	0	0	1	0
Palythoa heideri	18	18	14	22
Palythoa densa	2	0	4	5
Pocillopora sp	0	0	0	2
Isanemone sp	0	0	5	1
Green anemone	1	6	0	0
Sand anemone	0	5	0	0
Acanthopleura hirtosa	2	4	9	0
Austromegabalanus nigrescens	0	0	2	3
C. caputserpentis	0	0	1	0
Conus doreenensis	2	15	0	11
Cronia avellana	0	35	4	4
Ear shell	0	0	3	0
Echinometra mathaei	42	77	117	354
Giant limpet	1	0	0	0
Hermit crab	1	13	4	1
Isaurus tuberculata	1	1	0	1
Little red seastar	0	0	0	2
Mitra australis	1	0	0	1
Mitra scutulata	5	10	0	16
Morula brown	0	1	14	0
Mytilus galloprovincialis	0	0	1	0
Naxia sp.	0	0	1	0
Nudibranch	0	0	2	0
Octopus maorum	0	0	1	0
Patelloida alticostata	0	0	25	46
Polychaete	0	0	2	0
Pyrene bidentata	2	65	142	3
Ranella australasia	1	0	0	0
Rhinoclavis bidenticulata	0	5	1	0
Slipper limpet	2	30	9	0
Stomopneustus variolarus	0	0	1	0
Strombus mutabalus	0	0	0	1
Thais orbita	4	2	1	1
Tiny Sea hare	0	0	60	0
Trochus hanleyanus	0	0	3	1
Turbo intercostalis	0	2	3	0
Unbanded chiton	12	0	4	22
Vermitid	0	2	3	0
Species richness (S)	**16**	**17**	**29**	**19**
Number of individuals (N)	**97**	**291**	**439**	**497**

Table 2. The result summary of Tukey Post Hoc test. SE = Strickland East; SW = Strickland West; NP = North Point and SF = Strickland Far East.

Comparison	Estimate	P-value
SE - NP	-14.250	<0.001 ***
SF - NP	2.417	0.980
SW - NP	-6.167	0.207
SF – SE	16.667	0.031 *
SW – SE	8.083	0.002 **
SW – SF	-8.583	0.504

Note: * ** *** indicates significant at the ten percent, five percent,and one percent level, respectively.

Figure 4. Dendogram showing the clustering of invertebrate species composition at four sampling sites.

The difference in intertidal invertebrate assemblages at four sampling sites along Rottnest Island's coast was statistically significant (P < 0.05). Therefore, the prediction of the research was not in line with the result. Then, a further analysis using Tukey post hoc test revealed that the low abundance of intertidal invertebrates at Strickland East (97 individuals) was significantly different (P<0.001) with high of invertebrate abundance at North Point (439 individuals). Then, the cluster analysis showed that there were two main clusters of invertebrate species composition at Rottnest Island where North Point (29 invertebrate species) became a single cluster separated from another cluster consisted of three sampling sites (Strickland East, Strickland West and Strickland Far East) with species composition of 16, 17 and 19, respectively. This phenomenon might be resulted from the difference in anthropogenic disturbances at each sampling site. Strickland Bay which consist of three locations including Strickland East, Strickland West and Strickland Far East is a busy tourist spot where Strickland East is the most popular surfing location in Rottnest Island with many human activities such as surfing, snorkeling and sun bathing at the intertidal zone. Whilst North Point is a quite diving site where not so many human activities around intertidal area.

The low level of invertebrate abundance at Strickland East might be also resulted from anomalies of temperature in early 2011 for more than ten weeks affected by heatwaves. This event increased the temperature 2-4^{0}C above normal condition which highly correlated with the shift in community structure of invertebrate in the intertidal zone of Rottnest Island (Wernberg et al., 2012). He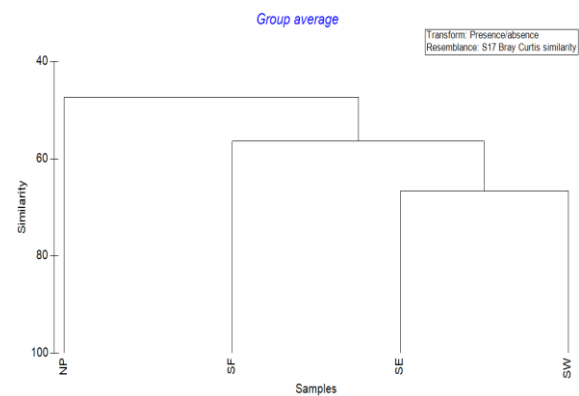atwaves also provided a significant change in structure and relative composition of benthic communities in the transitional ecosystem, such as at Comacchio Saltworks, Italy and Tabarca Marine Protected Area, Southeast Spain (Munari, 2011; Rubio-Potello et al., 2016). In addition, warmer temperature of sea waters might result in hypoxia which would decrease survival time of benthic species including macro-invertebrate (Vaquer-sunyer & Duarte, 2011).

A change in domination of habitat-forming species in Rottnest's marine ecosystem from kelp (Ecklonia radiata) to turf algae as a consequence of the heatwaves event in 2011 was also considered as the trigger of a shift in community structure of invertebrates (Wernberg et al., 2016). This because after the heatwaves, invertebrates could not find shelters and feeding area provided by kelp as the previous dominated ecosystem. This phenomenon ultimately leads to a shift in community structure of invertebrates because new turf algae habitats might only suitable for a certain invertebrate assemblage. A rise in sea water temperature which exceed the physiological threshold of invertebrates could also directly results in a change in community structure of invertebrates. Munari (2011) reported that in Comacchio Saltworks waters in Italy, there was a shift in dominance of invertebrate species. Before the heatwaves occurred in 2003, Annelids had greater abundance than Molluscs. However, after the heatwaves, Molluscs became more dominant species compare to Annelids in the transitional ecosystem.

On the other hand, a wide range of life temperature of Echinometra mathaei species, one of sea urchin species, had enabled them to dominate the intertidal zone at all sampling sites.

Rupp (1973) stated that the eggs temperature range of this species was between 28 and 36^0C. Whereas the adult individuals of this species could still survive at 40°C (McClanahan & Muthiga, 2001). Furthermore, the Leeuwin currents occurred in February 2011 might become another factor enabled this species to dominate all study sites because these currents delivered larvae of benthic organisms from the North pole to South-West coast of Australia including Rottnest's marine waters (Maxwell & Cresswell, 1981; Prince, 1995; Wernberg et al., 2012; Pearce & Feng, 2013).

4. Conclusion

Overall, it can be concluded that the difference in invertebrate abundance and species composition between the four sampling sites was resulted from the difference in anthropogenic disturbance at each sampling site. In the future, a consistent invertebrate monitoring program covering all intertidal sites in Rottnest Island needs to be conducted every year. The research should not only investigate the biological factor of invertebrates such as the abundance and species richness but should also observe chemical and physical factors affected their life such as nutrient, temperature, Ph and salinity. This integrated research should involve credible marine researchers from various field in order to obtain reliable data for management and conservation purposes.

Acknowledgements

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